STRIPLIN Environmental Associates

April 26, 2002
Wallace Reid
US Environmental Protection Agency
1200 Sixth Ave
Seattle, WA 98104

Re: Lower Willamette River, Portland Harbor Superfund Site
USEPA Docket No: CERCLA-10-2001-0240
Portland Harbor RI/FS Phase 1 – Precision Bathymetric Survey

Dear Mr. Reid:

This letter transmits the results of a multibeam bathymetric survey that took place in the Lower Willamette River from the confluence with the Columbia River to River Mile 15.6. The bathymetric survey was conducted by David Evans and Associates, Inc. between December 13, 2001 and January 14, 2002, during a period of high water. The methods used to collect and post-process the riverbed elevation data are provided in a report prepared by David Evans and Associates, Inc. (Attachment A). There were no deviations from the Work Plan, dated July 12, 2001.

The vertical accuracy of collected water depths was 0.5 ft, and the horizontal accuracy was 1 meter. The resulting data were processed using a grid size of 3 ft by 3 ft to generate a digital terrain model (DTM). The results of the survey are shown in both hillshade format (Figure 1a-k) and contours (Figures 2a-k). Water depths are referenced to the North American Vertical Datum of 1988 (NAVD88).

Per the Scope of Work, data are also transmitted digitally. The enclosed CD contains edited x, y, and z data and Autocad files of the x, y, z data and contour maps. If you have any questions, please give me a call at (206) 241-5185.

Sincerely,

Betsy D. Striplin
RI/FS Coordinator

Copies: Trey Harbert, Port of Portland, LWG Co-Chair
Bob Wyatt, NW Natural, LWG Co-Chair

ATTACHMENT A

Lower Willamette River
Multibeam Bathymetric Survey Report

DRAFT DOCUMENT: DO NOT QUOTE OR CITE
This document is currently under review by US EPA and its federal, state and tribal partners, and is subject to change in whole or in part.

Submitted to:
Striplin Environmental Associates, Inc.
222 Kenyon St NW
Olympia, WA 98502

Submitted by:
David Evans Associates, Inc.
2828 SW Corbett Ave
Portland, OR 97201

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1.0 INTRODUCTION

David Evans and Associates, Inc. (DEA), under contract with Striplin Environmental Associates, conducted a precision bank-to-bank multibeam bathymetric survey of the Lower Willamette River. The primary goal of the survey was to develop accurate data of current riverbed elevations from River Mile 0, at the confluence with the Columbia River, to River Mile 15.6, at the upper end of Ross Island. DEA also provided a Geographical Information System (GIS) database, which merged bathymetric data and upland topographic data obtained using airborne Light Detection and Ranging (LIDAR) by a separate contractor.

The results from this survey will be used to support sediment sampling during the remedial investigation, define shoaling and scour areas relative to previous surveys, and support future site investigations. Survey operations were conducted from December 13, 2001 through January 14, 2002. This report describes control used for the survey, data acquisition methodology, and data processing procedures. In addition to this report, deliverables include a set of full size drawings and project CD-ROMs, containing digital data, Arc/Info GRID files and AutoCAD drawing files of final maps.

2.0 DATUMS AND PROJECT CONTROL NETWORK

Conducting a survey on an established coordinate system, referenced by monuments, enables the survey to be reproduced at a later date with repeatable results. Using a coordinate system on a defined horizontal and vertical datum allows for utilization of data from other sources. For this survey, the horizontal datum is the North American Datum of 1983 through the 1991 adjustment (NAD83/91), State Plane Coordinate System (SPCS), Oregon North Zone. Units are International Feet (1 foot = 0.3048 meters exactly). Vertical datum for this survey is the North American Vertical Datum of 1988 (NAVD88). This vertical datum was selected due to the ease of use with a Global Positioning System (GPS) and will provide for a more accurate merge with LIDAR data. The geoid model used in processing of GPS observations was GEOID99.

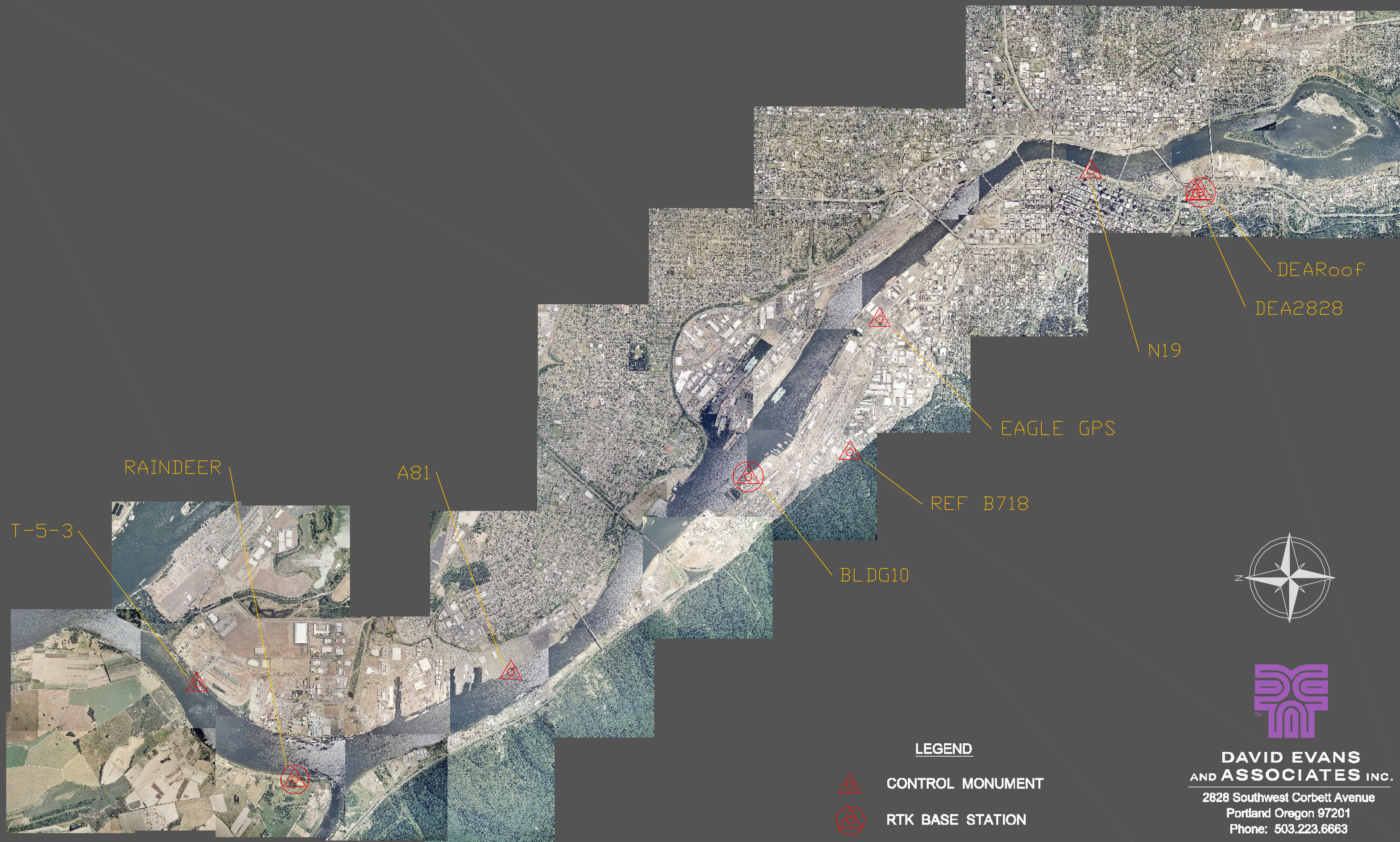
Prior to the survey, DEA established a control network based on NAD83/91, Oregon North Zone horizontal positions and NAVD88 elevations. As the primary vertical control for this survey was to be provided by real-time kinematic (RTK) GPS observations based on this control network, it was vital to the project to have an accurate ellipsoid separation model for on-the-fly conversion from the WGS84 ellipsoid (ellipsoid from which GPS heights are derived) to NAVD88. This required ties to monuments along the project corridor for which NAVD88 elevations were published. In addition, it was decided that the control network should be expanded to include monuments on which Port of Portland and U.S. Army Corps of Engineers gauging sites are based. By including these points in the control network, a conversion table was generated (Table 1) to aid in the conversion of data based on Columbia River Datum (CRD) or the National Geodetic Vertical Datum of 1929 through the 1947 adjustment (NGVD29/47).

Table 1. Vertical Datum Conversion.

River Mile	NAVD88 Elevation	NGVD29/47 Elevation	CRD Elevation
0.4	10.0’ 0.0’ -10.0’	6.8’ -3.2’ -13.2’	5.4’ -4.6’ -14.6’
1.3	10.0’ 0.0’ -10.0’	6.8’ -3.2’ -13.2’	5.4’ -4.7’ -14.7’
5.0	10.0’ 0.0’ -10.0’	6.7’ -3.3’ -13.3’	4.9’ -5.1’ -15.1’
9.8	10.0’ 0.0’ -10.0’	6.5’ -3.5’ -13.5’	4.7’ -5.3’ -15.3’
12.8	10.0’ 0.0’ -10.0’	6.5’ -3.5’ -13.5’	4.6’ -5.4’ -15.4’
15.6	10.0’ 0.0’ -10.0’	6.5’ -3.5’ -13.5’	4.6’ -5.4’ -15.4’

The control network included ties to the Oregon High Accuracy Reference Network (HARN) control monuments VAN CBL 0, NELSON and WACO. The network was constrained horizontally to the HARN monuments. The network was constrained vertically to VAN CBL 0 and two other first order vertical benchmarks B718 and N723. As the benchmarks could not be occupied for GPS measurements, closed differential level loops were run to points set in the proximity where GPS observations could be made. The project network included a horizontal position check on DEA2828, a prior established monument by DEA. The position obtained from the network adjustment missed DEA previous position by: North -0.03 feet, East -0.03 feet, Elevation 0.16 feet. Elevation checks were made to three monuments with recorded NGVD29/47 elevations and shifted to NAVD88 elevations using VERTCON software. Results of these checks are: A81 (-0.09 feet), EAGLE GPS 36 (0.02 feet), and T-5-3 (-0.15 feet). Figure 1 is a map of the control network for the Lower Willamette River. Table 2 represents coordinates and elevations for network monuments and copies of field notes from GPS observations.

FIGURE 1: CONTROL NETWORK FOR THE LOWER WILLAMETTE RIVER



DAVID EVANS AND ASSOCIATES INC.
2828 Southwest Corbett Avenue
Portland Oregon 97201
Phone: 503.223.6663

Table 2. Lower Willamette River, Control Network Coordinates.

Monument Designation	NAD83 OR North		NAD83 OR North		NAVD88	
	North m	East m	North ft	East ft	El m	El Ft.
A81	216879.768	2322669.168	711547.800	7620305.670	9.022	29.60
BLDG10	213233.670	2325671.863	699585.530	7630157.030	10.495	34.43
DEA2828	206352.805	2330026.319	677010.520	7644443.300	28.738	94.28
DEARoof	206281.052	2330042.744	676775.100	7644497.190	42.041	137.93
EAGLE GPS 3	211213.728	2328090.742	692958.430	7638092.990	10.146	33.29
N19	207968.621	2330368.700	682311.750	7645566.600	10.447	34.27
NELSON	202701.014	2326430.157	665029.570	7632644.870	125.250	410.93
RAINDEER	220200.425	2321017.341	722442.340	7614886.290	10.829	35.53
REF B718	211672.417	2326043.648	694463.310	7631376.800	12.600	41.34
REF N723	201209.507	2332677.212	660136.180	7653140.460	15.105	49.56
T-5-3	221705.879	2322489.162	727381.490	7619715.100	9.208	30.21
VAN CBL 0	225260.113	2325154.017	739042.370	7628458.060	9.220	30.25
WACO	209291.534	2305473.631	686652.010	7563889.870	75.229	246.81

3.0 BATHYMETRIC SURVEY

A high-resolution multibeam bathymetric survey was conducted to provide detailed three-dimensional data over the Lower Willamette River from River Mile 0 to River Mile 15.6.

3.1 SURVEY VESSEL AND CREW

The vessel for this survey was the *John B. Preston*, a 30-foot custom aluminum survey boat owned and operated by DEA. The vessel is equipped with an integrated navigation and data acquisition system, a custom mount for the SeaBat 8101 sonar head, and is ideal for shallow water survey operations in tight quarters.

The hydrographic survey crew consisted of a lead hydrographer and vessel operator/hydrographer from DEA. The crew has conducted numerous multibeam and side-scan sonar surveys and has had extensive training in hydrographic surveys.

3.2 POSITIONING AND NAVIGATION

Horizontal positions were acquired with an Applanix POS/MV Differential Global Positioning System (DGPS) and inertial navigation system. Differential correctors were obtained real-time via radio broadcasts from the Continuously Operating Reference Station (CORS) site at Appleton, Washington. POS/MV system integrates two GPS receivers with a motion reference unit. This system not only provides motion information (heading, roll, pitch, and heave) to compute X, Y, Z data from the multibeam sonar measurements, it also provides accurate inertial navigation through GPS outages for up to 30 seconds. This has always been a major problem with conventional DGPS equipment. Using conventional equipment near bridges and alongside ships, a typical environment in the Willamette River, causes satellite signals to be blocked and/or reflected from these structures (multipath), resulting in position jumps or large drifts in position that can exceed survey tolerances. The GPS/inertial positioning system enabled the survey vessel to run near ships at berth without jeopardizing positioning integrity from satellite signal multipath.

Position data was used in real-time to provide navigation information to the vessel operator and was time tagged and logged with multibeam and other ancillary data. The planned survey lines and the actual survey track are displayed with multibeam swath coverage in real-time on a monitor located at the helm to aid in a systematic survey of the area.

To check the accuracy of the positioning system, a secondary positioning system was used for real-time comparison. This system consisted of a pair of Trimble Model 4700 GPS receivers with Real-Time-Kinematic (RTK) positioning capabilities. One RTK GPS receiver was placed over an established monument with known horizontal and vertical positions. Figure 1 shows the location of monuments used for RTK GPS base station deployment. With the known values input into the receiver, this base receiver broadcast correctors to the rover RTK GPS receiver aboard the survey vessel. Position differences were displayed in real-time between the DGPS/Inertial positioning system and those obtained by RTK GPS based on the project control network. DGPS was used in the GPS/inertial positioning system solution rather than RTK GPS due to the robust performance of DGPS in a high multipath environment near ships, along side piers with overhead cranes and under bridges.

3.3 WATER SURFACE OBSERVATIONS

As all bathymetric data is time tagged and recorded relative to the water surface, accurate water surface observations in the vicinity of the survey are required to account for tides and changes in river flow. Water surface measurements were obtained by RTK GPS with on-the-fly (OTF) ambiguity resolution. An RTK GPS base station was deployed at three separate locations to provide real-time GPS correctors. RTK correctors were applied to the shipboard GPS for logging of water surface elevations at one-second intervals. An ellipsoid separation model was developed and used in Hypack MAX software for on-the-fly conversion from the WGS84 ellipsoid (ellipsoid from which GPS heights are derived) to NAVD88. One-second observations were graphically viewed and edited for outliers, artifacts from multipath, or loss of satellites. After editing of the one-second data, a 60-second average of RTK GPS observations was used for correcting multibeam soundings to NAVD88 elevations.

Water surface elevations obtained by RTK GPS were checked against established staff gauges installed previously by DEA at Port of Portland Terminals 2, 4 and 5 as well as Corps of Engineers staff gauges and the Morrison Bridge staff and automated gauge.

As a backup to RTK GPS observations, an automated water surface gauge was deployed in the vicinity of survey operations. This provided an accuracy comparison to the RTK

GPS data and an alternate source of water surface elevations. In addition, Morrison Bridge gauge data was downloaded from the U.S. Army Corps of Engineers web site (http://www.nwd-wc.usace.army.mil/cgi-bin/DataQuery) for the Willamette River in Portland. Data from the Morrison gauge is 0.3 feet higher than Columbia River Datum (CRD). To convert Morrison Bridge gauge readings to CRD, subtract 0.3 feet. The gauge readings are 5.1 feet below NAVD88. To convert to NAVD88, add 5.1 feet to gauge readings. All soundings for this survey were reduced to NAVD88 elevations in the delivered data set.

3.4 MULTIBEAM DATA ACQUISITION

Soundings were acquired with a Reson SeaBat 8101 multibeam bathymetric sonar using a frequency of 240kHz. The system records 101 soundings in a single sonar ping. Additionally, DEA's 8101 includes options such as a stick projector for enhanced shallow water performance and the ability to output side scan sonar imagery. The stick projector option on the Reson SeaBat 8101 improves the system performance in shallow water (depths less than 150 feet). Side scan imagery was recorded with the multibeam data and was displayed and used during editing of bathymetric data. Imagery was recorded in an XTF format and is available if required at a later date to aid in substrate delineation.

Multibeam data was conducted by running lines parallel with the shoreline for the length of the project. For this survey, the sonar head was mounted with a 15 degree offset angle for horizontal orientation of the outer starboard beam. This enabled coverage over a range of 90 degrees from nadir (straight down) to starboard and 60 degrees from nadir to port with a recorded depth every 1.5 degrees. Sonar swaths were recorded at a rate of 20Hz as the vessel transited along the survey track lines. With this configuration, shoreline data was collected as far up the bank as possible by making shoreline runs with the starboard side toward shore. This allowed mapping under piers and barges with a shallow draft. Survey lines offshore of the shoreline runs were clipped at 60 degrees (120 degree total swath width) during processing to improve data quality. Running with a 120-degree swath (60 degrees to port and starboard), the system provided 3.5 times the water depth coverage in a single pass. The total swath width of full coverage mapping in a single pass varied with the water depth.

The most vital measurements in a multibeam survey are heading and roll angles. To account for vessel heading, heave (vertical movement), pitch and roll, an Applanix POS/MV motion reference sensor was utilized. By utilizing vessel speed over ground provided by the DGPS and heading data, the POS/MV can isolate horizontal accelerations from vessel turns and provide highly accurate motion data. The POS/MV system was also used to record vessel heading (yaw) from which the sonar beam orientation was derived. The POS/MV provides a higher degree of accuracy for heading measurements than a conventional gyrocompass.

Multibeam data was recorded simultaneously on two systems. The primary acquisition system was a Triton Elics Isis system that provided precise time tagging of the sensor data and real-time data displays for quality control. The displays include real-time side scan imagery from the multibeam sonar. The secondary acquisition system was the navigation and survey control computer running Coastal Oceanographics HYPACK MAX software. Both systems acquired and time-tagged all sensor data including multibeam sonar slant-range measurements, position, heading, heave, pitch, and roll. The Coastal Oceanographics HYSWEEP program allowed the swath bathymetric data to be displayed as a painted color by depth image on the navigation screen. This real-time display gave the hydrographers immediate indications of data quality and coverage.

Detailed measurements of the sound velocity profile through the water column are crucial in multibeam surveys. Changes in the velocity profile will not only affect acoustic distance measurements, but can also cause refraction or bending of the sonar path as it passes through layers in the water column with different velocities. For this survey, a SeaBird SBE 19 SeaCat CTD profiler was used to measure conductivity, temperature, and depth at one-second intervals as the probe was lowered to just above the riverbed. The CTD measurements were used to compute an accurate velocity profile and were applied to the data during processing.

To confirm alignment of the multibeam sensor with the sonar swath and verify delay times applied to the time-tagged sensor data, a patch test was conducted. This consisted of a series of lines run in a specific pattern, which were used in pairs to analyze roll, pitch, and heading alignment angles with the sonar swath, as well as latency (time delays) in the time tagging of the sensor data.

To confirm the draft of the sonar head, lead line soundings were preformed at the sonar head and compared to logged multibeam depths.

4.0 DATA PROCESSING

Post-processing of multibeam data was conducted utilizing Caris HIPS multibeam analysis and presentation software. Patch test data was analyzed and any alignment corrections were applied. The Caris HIPS system allows simultaneous viewing of the side scan and multibeam data to analyze anomalies on the riverbed during post-processing. Water-level data was applied to adjust all depth measurements to NAVD88 from the RTK GPS processed data. Velocity profiles were generated from CTD measurements taken in the field and used to correct slant range measurements and compensate for any ray path bending.

Processing began with review of each survey line using Caris swath editor. Verified water surface correctors were applied to the data set at this time. Position and sensor data was reviewed and accepted. Sounding data was reviewed and edited for data flyers. Sounding data, including sonar beams reflecting from sediment in the water column or noise due to aeration in the water column, were carefully reviewed before flagged as rejected. In each case, data was not eliminated and can be re-accepted in the future if required.

After swath editing, all data was reviewed through the Caris HIPS subset editing program to ensure no flyers remained in the data set, or to re-accept data previously flagged in the swath editor. In the Caris subset editor, a set of lines was reviewed together for line to line comparison to ensure agreement to one another in a Caris session. A series of subsets were made to cover the survey area using multiple lines for each Caris session.

4.1 DATA EXPORT AND MAPPING

The project technical specifications call for no finer than a 10- by 10-foot grid of the data. To take advantage of the level of detail the multibeam bathymetric survey provided, a 3-foot gridded data set was exported from Caris HIPS. This gridding process selects the average depth from all accepted multibeam data on a 3- by 3-foot. Data was divided into sections that corresponded to final drawing sheet numbers and exported. All original data is archived at full resolution. If required at a later date, specific areas of interest can readily be remodeled at a higher resolution. It should be noted that this data is not biased for least depth as is the standard for a navigation survey and data should not be used for navigation purposes.

For bathymetric contouring, the 3-foot averaged export of accepted multibeam data was imported for each sheet into Plus-3 Terramodel software for generation of a digital terrain model (DTM). Elevation contours were generated from the DTM at a 2-foot interval based on NAVD88. After review of the DTM, the accepted data was exported as an ASCII text file by sheet. Due to the volume of data, some sheets contained over three million data points; additional subsections were developed for ease of input into Arc/Info GRID.

A sun-illuminated image of the multibeam data was generated in Caris HIPS at a 3-foot pixel resolution and georeferenced TIFF files for each sheet were exported. The sun-illuminated image was color coded by depth and demonstrates the extent of coverage over the survey area. Sun-illuminated images provide a more detailed presentation of the high-resolution multibeam bathymetric data than contouring and aid in the interpretation of river bedforms. The images were used as a quality control check to determine if subtle artifacts remained in the data set and incorporated in the deliverables.

4.2 GIS PROCESSING

LIDAR data ASCII files were converted to Arc/Info GRID raster format with 10-foot cells, and all data gaps were coded as “NODATA.” Bathymetry ASCII files for each sheet were converted to GRID format with 3-foot cell size and provided as a separate data set prior to merging with LIDAR data. The bathymetry sheet GRIDs were resampled to a 10-foot cell size, to reduce the data set and better match LIDAR resolution, and developed a mosaic with the LIDAR-derived upland GRID into one GRID for the entire survey. In areas where the bathymetry and upland data overlapped, the bathymetry data was given priority. Gaps where the two data sets did not overlap were coded as "NODATA." The merged bathymetry and upland GRID was clipped by sheet boundaries to provide smaller data sets. ESRI Arc/Info, Arc/GRID, AML and Arcview software were used for all GIS processing.

4.3 MULTIBEAM BATHYMETRIC DATA PRESENTATION

Multibeam bathymetric contours were imported into AutoCAD and presented as a series of bathymetric contour maps (B1-B7) at a scale of 1"=400'. Aerial photographs from a 2000 aerial survey were provided by the Port of Portland to use as a base map. The aerials provided an excellent reference to the bathymetric data.

Sun-illuminated imagery of the bathymetric data was overlaid on the aerial base maps and a set of Sun-Illuminated drawings (S1-S7) was developed in AutoCAD. The drawings included a color depth legend in NAVD88 and CRD to aid in the depth determination. The colors used to define the depth are from a rainbow spectrum that provides three-dimensional viewing of the drawings and reveal detailed riverbed relief when viewed with special glasses. The ChromaDepth glasses are available from Chromatek, Inc. at http://www.chromatek.com.

APPENDIX A

Field Notes from GPS Observations

(Presently only available in hard copy)